METHOD AND APPARATUS FOR MIXING CHEMICALS FOR USE IN CHEMICAL MECHANICAL POLISHING PROCESSES

Background of the Invention

Field of the Invention

The present invention relates generally to methods and apparatus for mixing chemicals used in semiconductor manufacturing processes and, more particularly, to methods and apparatus for mixing chemicals for use in chemical mechanical polishing processes.

Description of the Related Art

Chemical mechanical polishing (CMP) planarization techniques are commonly used in the manufacture of layered semiconductor devices. In typical CMP processes, a workpiece or wafer to be polished is pressed against a polishing pad under controlled conditions in the presence of a chemical mixture. The chemical mixture typically comprises a slurry including small, abrasive particles that abrade the surface of the wafer, and chemicals that etch and/or oxidize the surface of the wafer. When the pad and the wafer are moved with respect to one another, material is chemically and mechanically removed from the surface of the wafer to produce a polished or planarized surface.

Chemical mixtures used in CMP processes vary depending on the material to be removed from the surface of the wafer. If a metal surface is to be polished, the mixture may comprise, for example, a slurry containing a suspension of electrically charged alumina or silica particles and an oxidizer comprising, for example, hydrogen peroxide. If a nonmetal surface is to be polished, the mixture may comprise, for example, a slurry containing a suspension of electrically charged silica particles and, for example, ammonia or ammonium hydroxide.

In order to ensure consistent process results between wafers, it is necessary to precisely control the composition of the chemical mixture used. Prior art CMP systems typically include volumetric pumps that pump the various components of the mixture from bulk sources to a mix chamber where the components are mixed together. While

typically providing high throughput, such systems typically do not allow precise control of the mixture composition due to the limited precision of the volumetric pumps. Accordingly, a need exists for a CMP system in which the composition of the chemical mixture delivered to the wafer can be precisely controlled without adversely affecting throughput.

Summary of the Invention

In accordance with one aspect of the present invention, a method of preparing a fluid mixture comprising predetermined amounts of two or more fluids is provided. The method comprises the steps of providing a first vessel having a body and a neck extending upwardly from the body. The neck has a smaller cross-sectional area than the body. A first fluid is delivered to the first vessel to fill the body and at least a portion of the neck. A sight tube indicating an amount of the first fluid in the first vessel is read, preferably by an optical sensor. The delivery of the first fluid is discontinued when the sight tube indicates that a predetermined amount of the first fluid is in the first vessel. A second vessel is also provided. A second fluid is delivered to the second vessel. A sight tube indicating an amount of the second fluid in the second vessel is read, also preferably by an optical sensor. The delivery of the second fluid is discontinued when the sight tube indicates that a predetermined amount of the second fluid is in the second vessel. The predetermined amounts of the first and second fluids are then delivered to a mix chamber and mixed.

In accordance with another aspect of the present invention, a chemical delivery apparatus is provided, comprising a first vessel having a body and a neck extending upwardly from the body. The neck has a smaller cross-sectional area than the body. A fluid inlet is provided near a top of the neck. A fluid outlet is provided near a bottom of the body. A first sight tube port is provided near the top of the neck, and a second sight tube port is provided near the bottom of the body. A sight tube is connected between the first and second sight tube ports to indicate an amount of fluid in the first vessel. A first fluid source selectively communicates with the first vessel through the fluid inlet of the first vessel. A second vessel is also provided, comprising a fluid inlet and a fluid outlet. A second fluid source selectively communicates with the second vessel through

the fluid inlet of the second vessel. A mix chamber selectively communicates with the first and second vessels through the fluid outlets of the first and second vessels.

In accordance with another aspect of the present invention, a method of preparing a fluid mixture comprising predetermined amounts of two or more fluids is provided. The method comprises the steps of providing a vessel having a body and a neck extending downwardly from the body. The neck has a smaller cross-sectional area than the body. A first fluid is delivered to the vessel to fill a portion of the neck. A sight tube indicating an amount of the fluid in the vessel is read, preferably by an optical sensor. The delivery of the first fluid is discontinued when the sight tube indicates that a predetermined amount of the first fluid is in the vessel. A second fluid is then delivered to the vessel to fill a remaining portion of the neck and at least a portion of the body. The sight tube is read by the optical sensor, and the delivery of the second fluid is discontinued when the sight tube indicates that a predetermined amount of the second fluid is in the vessel. The predetermined amounts of the first and second fluids are then delivered to a storage chamber.

In accordance with another aspect of the present invention, a chemical delivery apparatus is provided, comprising a vessel having a body and a neck extending downwardly from the body. The neck has a smaller cross-sectional area than the body. First and second fluid inlets are provided near a top of the body. A fluid outlet is provided near a bottom of the neck. A first sight tube port is provided near the top of body, and a second sight tube port is provided near the bottom of the neck. A first fluid source selectively communicates with the vessel through the first fluid inlet. A second fluid source selectively communicates with the vessel through the second fluid inlet. A sight tube connected between the first and second sight tube ports indicates an amount of fluid in the vessel. A storage chamber selectively communicates with the vessel through the fluid outlet.

Brief Description of the Drawings

FIGURE 1 is a simplified schematic view of a first exemplary apparatus for mixing chemical slurries for chemical mechanical polishing of a workpiece;

FIGURE 2 is a front elevational view of one of the vessels of the apparatus of FIGURE 1;

FIGURE 3 is a right side elevational view of the vessel of FIGURE 2;

FIGURE 4 is a top plan view of the vessel of FIGURE 2;

FIGURE 5 is a simplified schematic view of a second exemplary apparatus for mixing chemical slurries for chemical mechanical polishing of a workpiece;

FIGURE 6 is a rear elevational view of one of the vessels of the apparatus of FIGURE 5;

FIGURE 7 is a right side elevational view of the vessel of FIGURE 6; and

FIGURE 8 is a bottom plan view of the vessel of FIGURE 6.

Detailed Description of the Preferred Embodiment

With reference to FIGURE 1, an apparatus for preparing a chemical mixture for use in CMP processing of semiconductor wafers is illustrated and designated generally by the reference number 20. In the illustrated embodiment, the apparatus 20 comprises a first fluid source 24 and a second fluid source 28. Depending on the surface material to be polished, the first fluid source 24 may comprise, for example, a slurry containing a suspension of electrically charged alumina particles. The second fluid source 28 may comprise, for example, hydrogen peroxide.

In the apparatus of FIGURE 1, the first fluid source 24 is connected by a first fluid line 32 to a first vessel 34. The second fluid source 28 is connected by a second fluid line 40 to a second vessel 44. In the illustrated embodiment, each of the first and second vessels 34, 44 generally comprises a lower body portion 48 and a neck portion 50 that extends upwardly from the body 48, preferably at one side of the body 48, as best illustrated in FIGURES 2-4. A fluid inlet 54 is provided near a top of the neck 50, and a fluid outlet 56 is provided near a bottom of the body portion 48. The first and second fluid lines 32, 40 are connected to the fluid inlets 54.

Each of the vessels 34, 44 preferably includes an upper sight tube port 60 near the top of the neck 50, and a lower sight tube port 62 near the bottom of the body portion 48. A sight tube 66 preferably is connected between the upper and lower sight tube ports 60, 62, as illustrated schematically in FIGURE 1. A vent opening 70 (see FIGURE 4) preferably is also provided near the top of the neck 50.

In the illustrated embodiment, each of the sight tubes 66 comprises a tubular fluid conduit 74 having an upper end connected to the upper sight tube port 60 and a

lower end connected to the lower sight tube port 62. As is well known in the art, fluid flows out of the lower sight tube port 62 and into the conduit 74 as the vessel 34, 44 is filled with fluid. The height of the fluid column in the sight tube 66 indicates the level of the fluid in the vessel 34, 44. Based on the dimensions of the vessel 34, 44, the volume of the fluid in the vessel 34, 44 can then be determined.

Preferably, the height of the fluid column in the sight tube 66 is sensed by an optical sensor (not shown). The optical sensor sends a signal to a programmable controller (not shown), which communicates with various pumps and/or valves in the apparatus. In the simplified schematic of FIGURE 1, a single pump 80 and a single valve 82 are provided in each of the first and second fluid lines 32, 40 between the fluid sources 24, 28 and the vessels 34, 44.

Optical sensors are well known in the art and can be purchased from a number of different suppliers, including Omron Electronics, Inc., of Schaumburg, Ill. The precision of a typical optical sensor in sensing the height of a fluid column in a sight tube (and, thus, the fluid level in a vessel to which the sight tube is attached) is about ±1 mm of fluid height at 99 percent confidence. Accordingly, given the limited precision of such sensors, as the volume of fluid per unit height in a vessel is decreased, the precision with which it is possible to measure the total volume of fluid in the vessel is increased.

In order to decrease the volume of fluid per unit height in a vessel, and thus increase the precision with which the total volume of fluid in the vessel can be determined, the cross-sectional area of the vessel must be decreased. As the cross-sectional area of the vessel is decreased, however, the height of the vessel must be increased to maintain the same total volume of the vessel. This can be problematic, because the maximum height of the vessel is typically constrained by the environment in which the vessel is located.

Each of the vessels 34, 44 of the apparatus of FIGURE 1 comprises a body portion 48 having relatively large cross-sectional area and a neck portion 50 having a smaller cross-sectional area. Preferably, the cross-sectional area of the neck portion 50 of each of the vessels 34, 44 is less than about one-third the cross-sectional area of the

body portion 48. In the illustrated embodiment, the cross-sectional area of the neck portion 50 of each vessel 34, 44 is about 20 percent that of the body portion 48.

When the fluid level in the vessel 34, 44 is below the neck portion 50 thereof, the precision with which the total volume of fluid in the vessel 34, 44 can be determined is relatively low, due to the relatively large cross-sectional area of the body portion 48 and the limited precision of the optical sensor. As the vessel 34, 44 is filled and the fluid level rises into the neck portion 50, however, it is possible to more precisely determine the total volume of fluid in the vessel 34, 44, assuming the volume of the body portion 48 of the vessel 34, 44 is known. Because the cross-sectional area of the neck 50 is relatively small, the fluid level in the neck 50, and thus the height of the fluid column in the sight tube 66, rises or falls significantly as the volume of fluid in the vessel 34, 44 is increased or decreased. As a result, the volume of fluid in the vessel 34, 44 can be sensed more precisely by the optical sensor. At the same time, because of the relatively large cross-sectional area of the body 48 of the vessel 34, 44, the total volume of the vessel 34, 44 can be substantial without requiring that the height of the vessel 34, 44 be excessive.

With reference again to FIGURE 1, in operation, the controller opens the valve 82 and activates the pump 80 to pump the first fluid through the first fluid line 32 from the first fluid source 24 to the first vessel 34. The fluid level in the vessel 34 rises through the body 48 of the vessel 34 and into the neck 50. As the vessel 34 is filled, the fluid column in the sight tube 66 rises. The optical sensor senses the height of the fluid column in the sight tube 66. When the column reaches a predetermined height indicating that the desired amount of fluid is in the vessel 34, the sensor sends a signal to the controller to close the valve 82 and deactivate the pump 80.

In a similar manner, the controller opens the valve 82 and activates the pump 80 of the second fluid line 40 to pump the second fluid from the second fluid source 28 to the second vessel 44. The fluid level in the second vessel 44 similarly rises through the body 48 of the vessel 44 and into the neck 50. As the vessel 44 is filled, the fluid column in the sight tube 66 rises. The optical sensor senses the height of the fluid column in the sight tube 66. When the column reaches a predetermined height

indicating that the desired amount of fluid is in the vessel 44, the sensor sends a signal to the controller to close the valve 82 and deactivate the pump 80.

In the arrangement of FIGURE 1, each of the first and second vessels is connected to a mix chamber 100 by a fluid line 102. The fluid lines 102 are connected to the fluid outlets 56 (see FIGURES 2-3) of the vessels 34, 44. When the vessels 34, 44 are filled to the desired levels (taking into account the amount of fluid in the fluid lines 102 between the vessels 34, 44 and the mix chamber 100), the controller opens a valve 108 in each of the fluid lines 102 and delivers the precisely measured contents of vessels 34, 44 into the mix chamber 100. Depending on the particular arrangement of the apparatus, additional pumps may be necessary to pump the fluids through the fluid lines 102 to the mix chamber.

The mix chamber 100 may include a mechanical mixer (not shown) to stir the contents of the mix chamber 100 and prevent the mixture from stagnating or separating. In the illustrated embodiment, a recirculation line 110 is provided for such purpose. The mixture exits the mix chamber 100 and is pumped through the recirculation line 110 and back into the mix chamber 100. In the illustrated arrangement, a three-way valve 118 is provided in the recirculation line 110 so that a portion of the mixture can be diverted to the workpiece (not shown) for use in the CMP process.

It is to be understood that the apparatus 20 illustrated schematically in FIGURE 1 is merely exemplary. Those skilled in the art will recognize that, depending on the particular process to be carried out, alternative arrangements may include a greater or lesser number of vessels and accommodate additional or different fluids. In addition, depending on the precision with which it is necessary to measure the various components of the chemical mixture, only certain of the vessels may have the large cross-sectional body and smaller cross-sectional area neck configuration of the vessels of the apparatus of FIGURE 1.

With reference now to FIGURE 5, a simplified schematic view of a second exemplary apparatus 200 for preparing chemical mixtures is illustrated. In the illustrated embodiment, the apparatus 200 comprises a first fluid source 210 and a second fluid source 212. Again, depending on the surface material to be polished, the first fluid source 210 may comprise, for example, a slurry containing a suspension of

electrically charged silica particles. The second fluid source 212 may comprise, for example, deionized water.

In the arrangement illustrated in FIGURE 5, the first fluid source 210 is connected by a first fluid line 218 to a mix vessel 220. The second fluid source 212 is connected by a second fluid line 222 to the mix vessel 220. As best illustrated in FIGURES 6-9, the mix vessel 220 generally comprises a body portion 230 and a neck portion 232 that extends downwardly from the body 230, preferably at one side of the body 230. A pair of fluid inlets 236 are provided near a top of the body 230. A fluid outlet 238 is provided near a bottom of the neck 232. The first and second fluid lines 218, 222 (FIGURE 5) are connected to the fluid inlets 236 of the vessel 220.

The vessel 220 preferably includes an upper sight tube port 244 near the top of the neck 232, and a lower sight tube port 246 near the bottom of the body portion 230. A sight tube 250 preferably is connected between the first and second sight tube ports 244, 246, as illustrated schematically in FIGURE 5. A vent opening (not shown) and a recirculation inlet 256 preferably are also provided near the top of the body 230.

Fluid flows out of the lower sight tube port 246 and into the sight tube 250 as the vessel 220 is filled with fluid. The height of the fluid column in the sight tube 250 indicates the level of the fluid in the vessel 220. Preferably, the height of the fluid column in the sight tube 250 is sensed by an optical sensor (not shown), which sends a signal to a programmable controller (not shown). The controller communicates with various pumps and/or valves in the apparatus. In the simplified schematic of FIGURE 5, a single pump 262 and a single valve 264 are provided in each of the fluid lines 218, 222 between the fluid sources 210, 212 and the vessel 220.

As illustrated in FIGURES 6-8, the body portion 230 of the vessel 220 has a relatively large cross-sectional area. The neck portion 232 has a smaller cross-sectional area. Preferably, the cross-sectional area of the neck portion 232 is less than about one-third that of the body portion 230. In the illustrated embodiment, the cross-sectional area of the neck portion 232 of the vessel 220 is about 21 percent that of the body portion 230.

The vessel 220 preferably includes a transitional region 270 between the body portion 230 and the neck 232, as best illustrated in FIGURE 6. Preferably, the cross-

sectional area of the transitional region 270 decreases progressively from the body portion 230 to the neck 232 to facilitate fluid drainage from the vessel 220. In the vessel 220 of FIGURES 6-8, the cross-sectional area of the neck 232 similarly decreases from the transitional region 290 to the bottom of the neck 232 to facilitate drainage from the vessel 220.

With reference to FIGURE 5, in operation, the controller opens the valve 264 and activates the pump 262 to the first fluid through the fluid line 218 from the first fluid source 210 to the vessel 220. The fluid rises into the neck portion 232 of the vessel 220. Because of the relatively small cross-sectional area of the neck portion 232, the fluid level in the neck 232, and thus the height of the fluid column in the sight tube 250, rises significantly as the volume of fluid in the neck 232 is increased. The volume of the first fluid in the neck 232 can thus be precisely determined by the optical sensor. When the fluid column reaches a predetermined height indicating that a desired volume of fluid is in the neck portion 232, the sensor sends a signal to the controller to close the valve 264 and deactivate the pump 262.

The controller then opens the valve 264 and activates the pump 262 of the second fluid line 222 to pump the second fluid from the second fluid source 212 to the vessel 220. The fluid level in the vessel 220 rises through the remaining part of the neck 232 and into the body portion 230 of the vessel 220. As the vessel 220 is filled, the fluid column in the sight tube 250 rises. The optical sensor senses the height of the fluid column in the sight 250 tube. When the column reaches a predetermined height, the sensor sends a signal to the controller to close the valve 264 and deactivate the pump 262.

The vessel 220 illustrated in FIGURES 5-8 is particularly advantageous when a desired mixture includes a substantially greater volume of one component than another component. The smaller volume component is first delivered to the vessel 220 to fill the neck 232 of the vessel 220. Because of the smaller cross-sectional area of the neck 232, the precise volume of the smaller volume component in the neck 232 can be precisely determined. The larger volume component, which need not be measured as precisely, can then be delivered to the vessel 220 to fill the body 230 of the vessel 220.

In the arrangement of FIGURE 5, a recirculation line 290 is provided to prevent the mixture from stagnating. The mixture exits the vessel 220 through the fluid outlet 238 and is pumped through the recirculation line 290 and back into the vessel 220 through the recirculation inlet 256. In the illustrated arrangement, a three-way valve 294 is provided in the recirculation line 290 so that a portion of the mixture can be diverted to the workpiece (not shown) for use in the CMP process.

It is to be understood that the apparatus illustrated in FIGURE 5, too, is merely exemplary. Those skilled in the art will recognize that, depending on the particular process to be carried out, alternative arrangements may include a greater of vessels and accommodate additional or different fluids. In addition, depending on the precision with which it is necessary to measure the various components of the chemical mixture, only certain of the vessels may have the large cross-sectional body and smaller cross-sectional area neck configuration of the vessel of the apparatus of FIGURE 5.

Although the invention has been disclosed in the context of certain preferred embodiments and examples, it will be understood by those skilled in the art that the present invention extends beyond the specifically disclosed embodiments to other alternative embodiments and/or uses of the invention and obvious modifications and equivalents thereof. Thus, it is intended that the scope of the present invention herein disclosed should not be limited by the particular disclosed embodiments described above, but should be determined only by a fair reading of the claims that follow.